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The effect of different drying methods on cuspal displacement resulting from stress-induced shrinkage of demineralized dentin

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ABSTRAK

Bonding pada restorasi dengan bahan resin komposit biasanya memerlukan prosedur pengeringan pada permukaan dentin, akan tetapi prosedur pengeringan itu sendiri kemungkinan dapat menyebabkan matriks kolagen dalam dentin mengalami kolaps, yang selanjutnya dapat mengakibatkan dentin yang telah didemineralisasi mengalami pengkerutan. Tujuan penelitian ini adalah untuk mengetahui pengaruh bebeberapa macam cara pengeringan yaitu *blot*, *mildly* dan *strongly* terhadap pergeseran kuspal gigi yang disebabkan oleh adanya tekanan pengkerutan pada dentin yang telah didemineralisasi. Pada penelitian ini digunakan 30 gigi premolar yang utuh dan bebas karies. Gigi disimpan di dalam larutan Chloramin T 1%. Akar gigi dipotong 3 mm di bawah cemento-enamel junction (CEJ). Kemudian dilakukan preparasi kavitas MOD. Untuk mengukur besarnya pergeseran kuspal gigi digunakan Direct Current Diferential Transformers (DCDTs). Setiap gigi dilakukan pengetsaan selama 15 detik dengan asam *phosphoric* 37,5% dan kemudian dicuci selama 10 detik dengan semprotan air. Pengukuran pergeseran kuspal gigi dilakukan pada waktu *baseline* (5 menit) dan pada waktu prosedur pengeringan (20 detik). Data kemudian dianalisis dengan analisis varians satu jalur diikuti oleh test Tukey's. Pergeseran kuspal gigi mencapai 6.5 µm terjadi pada waktu dilakukan prosedur pengeringan. Pengeringan *blot* menghasilkan pergeseran kuspal gigi yang terkecil (2.5 µm) disbanding metode pengeringan lainnya ($p<0.05$), sedangkan pengeringan *strongly* menghasilkan pergeseran kuspal gigi yang terbesar ($p<0.05$). Terdapat perbedaan yang tidak signifikan pada pergeseran kuspal gigi antara pengeringan *mildly* and *blot* ($p>0.05$). Dari penelitian ini direkomendasikan untuk menggunakan pengeringan *blot* atau *mildly* karena pergeseran kuspal gigi yang dihasillkan oleh kedua metode tersebut hampir sama dan jauh lebih kecil dibandingkan pengeringan *strongly*, sehingga kemungkinan terjadinya kolaps matriks kolagen dapat dicegah. *Maj. Ked. Gi.* 2006; 13(2):111-115

Kata kunci: pengeringan *blot*; pengeringan *mildly*; pengeringan *strongly*; pergeseran kuspal gigi, tekanan pengkerutan, dentin demineralisasi

ABSTRACT

Bonding of resin composite restorative materials to teeth usually involves drying of dentin surfaces, however drying procedure may cause collagen matrix within dentin to collapse, which in turn induce shrinkage of demineralized dentin. The purpose of this study was to investigate the effect of difference drying methods, namely blot drying, mildly drying and strongly drying on cuspal displacement resulting from stress-induced shrinkage of demineralized dentin.Thirty intact, caries free human maxillary premolars extracted for orthodontic reasons were used in this study. The teeth were stored in 1% Chloramine T solution. The root was removed from each tooth 3 mm apical to cemento-enamel junction (CEJ), by means of a slow speed diamond saw with water coolant. An MOD cavity was then prepared in each tooth. Direct Current Differential Transformers (DCDTs) were used in this study to detect linear cuspal displacement. Each tooth was etched with phosphoric acid 37.5% for 15 sec and rinsing with an air-water spray for 10 sec. Cuspal displacement was measured during baseline for 5 min and during each drying procedure for 20 sec. The data were analyzed using one way ANOVA followed by Tukey's test.Cuspal displacement occurred during all drying procedures for up to 6.5 µm. Blot drying produced the least cuspal displacement of 2.5 µm than other drying methods ($p<0.05$), whereas strongly drying lead to greatest cuspal displacement ($p<0.05$). No significant differences occurred in cuspal displacement between mildly and blot drying ($p>0.05$).Since blot and mildly drying produced the similar amount of cuspal displacement, which were significantly less than strongly drying, it is recommended to use both drying methods to prevent the collapse of collagen matrix within dentin. Maj. Ked. Gi. 2006; 13(2):111-115

Key words: *blot dryin, mildly drying, strongly drying, cuspal displacement, stress-induced shrinkage, demineralized dentin*

INTRODUCTION

Recent adhesive systems require that acid-etched dentin surface be dried with an air stream prior to applying the adhesive agents.[1] It is widely documented that water plays an important role in maintaining the three-dimensional structure of collagen due to dentin consists of approximately up to 22% water by volume.[2, 3] It has been suggested that dimensional change of dentin may occur if the water content is disturbed by drying procedure. Several study showed that dehydration of dentin causes volumetric shrinkage.[2,4,5] Since most of water in the demineralized matrix is between collagen fibrils, its removal causes shrinkage by disappearances of interfibrillar spaces, bringing the fibrils in closer approximation. Previous study found that when exposed to air-drying, dentin shrank by approximately 65% in volume, and 22% in a linear shrinkage.[6]

Similar to the stress-induced polymerization shrinkage phenomenon, it has been assumed that a tooth is under considerable contraction stress following drying as dentin has viscoelastic (time-dependent) properties.[7] This property is inherent in dentin since it consists of a composite structure with microscopic hydroxyapatite crystal embedded in matrix collagen biopolymers.[8] Shrinkage stresses, which occur in dentin, can cause displacement of cusps from their original position.[9,10]

Previous investigators have demonstrated that air-dried easily removed non-bound water and causes collagen matrix to collapse, allowing the collagen fibrils to come closer together, resulting in shrinkage of the demineralized dentin matrix.[11,12,13] They also reported that the collapse of the matrix interferes with monomer uptake and may make the bonds less durable. However, no study has attempted to investigate the cuspal displacement due to drying procedures. Therefore, the variety of drying methods needs to be carried out in order to search for the least shrunken dentin. The aim of this study was to investigate the effect of different drying methods, namely blot, mildly, and strongly drying on cuspal displacement, which associate with stress-induced shrinkage of demineralized dentin.

MATERIALS AND METHODS

Thirty intact, caries free human maxillary premolars extracted for orthodontic reasons were used in this study. The project was approved by the Ethics in Human Research Committee, University of Melbourne. The teeth were stored in 1% Chloramine T solution in distilled water (Sigma-Aldrich Co., St. Louis, MO, USA). The root was removed from each tooth 3 mm apical to the cemento-enamel junction (CEJ), by means of a slow speed diamond saw with water coolant (Struers, Ballerup, Denmark). A square plastic block (4 cm square and 5 mm thick) with a hole drilled at its center was used to mount each tooth. An 18-gauge needle was inserted into the hole, and the tooth was attached to the block using cyano-acrylate cement (M-Bond 200, Micro-Measurements Group Inc., Raleigh, NC, USA), and subsequently covered by epoxy resin (Araldite, Vantico AG, Basel, Switzerland) to the level of the CEJ. An MOD cavity was then prepared in each tooth with bucco-palatal width of one third of the inter-cuspal width and the depth of the proximal boxes terminated approximately 1 mm above the CEJ. The occlusal depth was approximately 3 mm.

Direct Current Differential Transformers (DCDTs, model 7 DCDT-050, Hewlett Packard, Rockville, MD, USA) were used in this study to detect linear cuspal displacement. The devices were calibrated to an accuracy of $\pm$ 0.5 μm. Two DCDTs were mounted on adjustable arms such that the tip of each rod could be attached to buccal or lingual enamel within a shallow depression near the cusp tip (Figure 1). The DCDTs were aligned perpendicular to the tooth axis in a bucco-lingual direction. The placement of DCDTs on either side of the tooth could detect any horizontal displacement of the tooth away from the neutral position. Measurements of the two cusps were combined to provide a net inward or outward cuspal displacement (in μm). Data from the DCDTs were recorded on a computer using Labview software (National Instruments Corp, Austin, TX). All of the data obtained were managed in Excel software (Microsoft 2003) as linear cusp deflection. A hydrostatic pressure of 1.3 kPa was applied throughout all procedures to imitate physiological pulp pressure.[14]

Teeth were randomly assigned into 3 groups of 10 each. Before the restorative procedures were performed, a baseline was established for 5 minutes. Teeth then were etched with phosphoric acid 37.5% for 15 seconds and rinsing with an air-water spray for 10 seconds. In group 1, dentin was kept moist and a sponge applicator was used to remove the excess of water (blot drying). In group 2, dentin was mildly air-dried with a compressed oil-free air-spray from a triplex syringe approximately 2 cm away from the surface at 45^0 in order only to remove excess water.[15] In group 3, dentin was strongly air-dried with full force at the same manner as group 2. All groups were air-dried for 20 seconds and cuspal displacement was measured during drying procedures.

A one way ANOVA (General Linear Model) was used to analyze the effect of different drying methods on the cuspal displacement and post hoc comparisons were conducted using Tukey's test. All analysis was performed at the 0.05 level of significance (Minitab Inc., State College, PA, USA).

RESULTS

A stable and insignificant cuspal displacement occurred in all specimens during baseline. All of the cusps of the teeth moved inwardly (buccal and lingual cusps moved closer each other) indicating that contraction stress occurred in the response to different drying methods. Inward cuspal displacement occurred substantially (mean: 6.5 μm) during strongly drying. In contrast, blot and mildly drying produced less cuspal displacement (mean: 2.5 μm and 3.2 μm respectively) (Figure 2).

With regard to the significance of cuspal displacement (Table 1), strongly drying produced the greatest inward cuspal displacement than other drying methods ($p<0.05$), while blot drying induced the least inward cuspal displacement ($p<0.05$). Even though mildly drying generated the greater inward cuspal displacement, it was not significantly different from blot drying ($p>0.05$).

DISCUSSION

The development of the moist bonding technique has led to higher bond strengths by preventing the collapse of demineralized dentin.[16] However, no study has addressed the satisfactory degrees of dentin surface moisture in preventing collapse of collage fibers, which in turn leading to induce shrinkage of demineralized dentin. This study was attempted to investigate the different drying methods specifically blot, mildly and strongly drying on the cuspal displacement resulting from shrinkage stress. The results confirm the previous study that different drying methods produced different degree of shrunken dentin matrix.

The cusps of teeth can move either inwardly if stress applied on to dentin or outwardly if stress relieved due to viscoelastic (tiome-dependent) properties of dentin.[7] The apatite filler phase of dentin contributes most of the compressive strength, while the collage phase provides elasticity and stress distribution.[17] These properties of dentin are considerable importance for understanding the mechanical properties of calcified tissue in general, and for understanding alterations in the biomechanical response to a wide variety of restorative dental procedures.[5]

In the effort to amplify cuspal displacement, an MOD cavity was employed in all teeth in this study, since this type of preparation is able to maximize cuspal displacement. The larger the cavity size, the greater the cusp displacement. This phenomenon can be explained by two points: firstly, there is less tooth structure left in large cavities, which means more flexibility of the cusps and more compliance with expansion and contraction phenomena.[10,18] Secondly, the extensive and deep cavity causes the loss of tooth rigidity when the marginal ridges are removed.[9]

The DCDTs were used in this study because they can detect any cuspal displacement due to stress-induced shrinkage of very short duration during drying procedures, and recorded data can be expressed quantitatively in micrometers of cusp displacement. Consequently, DCDTs can be related more closely to the clinical situation.[19] In addition, DCDTs can be easily isolated from the wet environment, which occurs during rinsing, without interfering with the measurement of cuspal displacement by using rubber dam sheets that covered the rods of the DCDTs.

The collagen fibrils of dentin collagen are about 100 nm in diameter and dentin collagen is more heavily cross-linked than dermal or tendon collagen.[20] They seem to be made up of smaller micro-fibrils separated by spaces filled with water. During drying, the water occupying the spaces between collagen micro-fibrils is lost by evaporation. Once dentin is demineralized during acid etching, the collagen fibers lose their surrounding structural support. The original rigid support, which was tightly packed apatite crystal, is replaced with water during acid etching and rinsing. If one dries the water-supported demineralized dentin surface with an air blast, it causes shrinkage of demineralized dentin matrix by disappearances of interfibrillar spaces, bringing the fibrils in closer approximation.[15,21] Surface tension forces act to collapse the collagen fibril network to a volume that was only 65% of its original volume.[6] According to Versluis [22], tooth deformation due to shrinkage stress can be quantified by measuring the displacement or movement of cusps, and the measurement offers the closest measurable relationship with shrinkage. Thus, in this study the dimensional changes (shrinkage) of human dentin that produced stresses of demineralized dentin were calculated by measuring displacement of cusps.

Air spray used in mildly and strongly drying evaporate more water from between collagen microfibrils, thereby stiffening the network in more collapse than applicator sponge used in blot drying.[15,23] As a consequence, mildly and strongly drying produced greater inward cuspal displacement than blot drying. Mildly drying induced insignificant different from blot drying in terms of cuspal displacement because the moisture was still maintained on dentin surface using both drying methods, resulting in preventing the collapse of collagen microfibrils network at different degrees.[23] In contrast, strongly drying removed most water occupying the space between the collagen microfibrils, leading to disappearing of interfibrillar spaces and forming the weak interpeptide bonds that renders the matrix shrunk, stiff and practically not in permeable to resin adhesives.[12]

Dried matrix can expand only if the stabilizing forces of collapsed matrix can be broken, particularly the H-bond between peptides. What is required is a solvent capable of forming H-bonds than do adjacent peptides.[21] The solvent should wet the dentin matrix, penetrate into it, and can expand shrunken collagen microfibrils and promote monomer diffusion into dentin, producing a durable bonding between adhesive resin and dentin surface.[12,13] Thus, more research is needed in the future, specifically concerning a variety of solvents, which are able to expand the shrunken collagen matrix, for promoting the infiltration completely of resin monomer to the depth of demineralized dentin matrix.

CONCLUSION

Based on the results of this study, either blot drying or mildly drying is recommended to be employed in drying the surface of dentin during resin composite restoration since both methods produced less cuspal displacement resulting from stress-induced shrinkage of demineralized dentin. However, further study is required to search for solvents that are able to expand the shrunken collagen matrix, hence, the resin monomer can infiltrate completely to the depth of demineralized dentin matrix, resulting in a durable bonding between adhesive resin and dentin surface.

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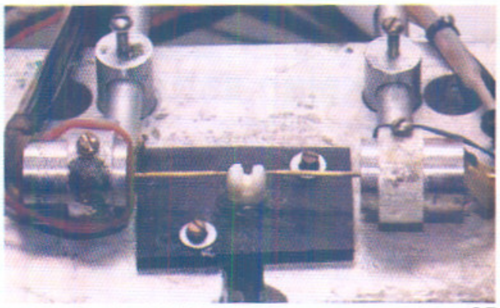

Figure 1. Tooth with MOD cavity was contacted to CDTs.

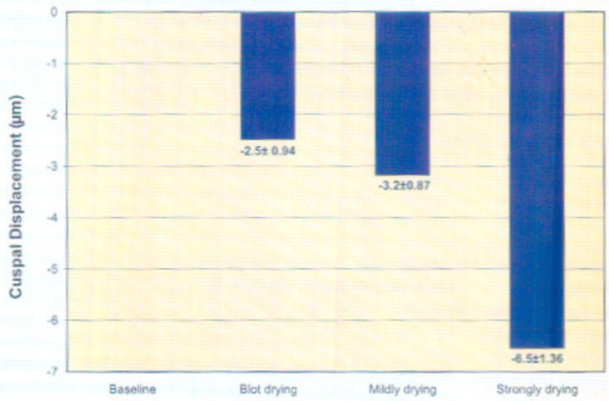

Figure 2. Column chart of the mean ± SD (with n = 10) of cuspal displacement using different drying methods. Negative values indicate inward cuspal displacement (contraction of the cusps occurred).

Table 1. Statistical analysis using one-way ANOVA of cuspal displacement resulting from different drying methods

Source of variation	DF	Seq SS	Adj SS	Adj MS	F	P-value
Drying methods	2	94.307	94.307	47.154	40.54	0.000
Error	27	31.403	31.403	1.163		
Total	29	125.710				